

UNITED STATES PATENT APPLICATION

**ADAPTIVE CHANNELIZATION SCHEME
FOR HIGH THROUGHPUT MULTICARRIER SYSTEMS**

INVENTORS:

Ali S. Sadri

Alexander A. Maltsev

Vadim S. Sergeyev

**Law Offices of John C. Scott, LLC
7860 North Hayden Road, Suite LLL102
Scottsdale, AZ 85258**

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The present application claims the benefit of U.S. Provisional Application Serial No. 60/536071, filed Jan 12, 2004, entitled "A SYSTEM APPARATUS AND ASSOCIATED METHODS FOR HIGH THROUGHPUT WIRELESS NETWORKING."

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FIELD OF THE INVENTION

The invention relates generally to wireless communications and, more particularly, to channelization schemes for use in wireless systems.

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BACKGROUND OF THE INVENTION

In some multicarrier communication technologies, such as orthogonal frequency division multiplexing (OFDM) systems and discrete multitone (DMT) systems, efforts are being made to achieve a higher overall communication throughput. In some instances, higher throughput is being achieved by increasing the bandwidth of multicarrier signals and/or increasing the number of subcarriers used within a multicarrier signal. In some OFDM-based wireless networking technologies, for example, techniques are being developed that allow several OFDM channels (e.g., several IEEE 802.11a channels) to be teamed together to achieve a higher throughput channel for a device. When such channel teaming is implemented, there is a possibility that other devices communicating on one or more of the teamed channels (e.g., within a neighboring basic service set (BSS) in a wireless network) may create interference within the teamed channel that can compromise the quality of the corresponding communication.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram illustrating an example wireless apparatus in accordance with an embodiment of the present invention;

5 Figs. 2, 3, and 4 are channel usage diagrams illustrating possible operational scenarios for a high throughput communication device in accordance with embodiments of the present invention; and

Fig. 5 is a flowchart illustrating a method for use in implementing adaptive channelization within a multicarrier device in accordance with an embodiment of the present invention.

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DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings that show, by way of illustration, specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. It is to be understood that the various embodiments of the invention, although different, are not necessarily mutually exclusive. For example, a particular feature, structure, or characteristic described herein in connection with one embodiment may be implemented within other
15 embodiments without departing from the spirit and scope of the invention. In addition, it is to be understood that the location or arrangement of individual elements within each disclosed embodiment may be modified without departing from the spirit and scope of the invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the
20 appended claims, appropriately interpreted, along with the full range of equivalents to which the claims are entitled. In the drawings, like numerals refer to the same or similar functionality throughout the several views.

The present invention relates to adaptive channelization techniques and structures for use in multicarrier communications. A high throughput (HT) multicarrier
25 communication channel is divided into multiple frequency sub-channels. The division

of the communication channel allows the individual sub-channels to be processed separately. A communication device that is operative within the system may determine which of the available sub-channels to use for a particular wireless link based on, for example, channel state information that may be indicative of current channel usage.

5 The communication device may then communicate with a remote entity using the identified sub-channels. In at least one embodiment, the frequency sub-channels that are used to make up the high throughput multicarrier channel are predefined channels. For example, in one implementation for use in a wireless networking environment, a high throughput multicarrier channel is formed using multiple 20 megaHertz (MHz)
10 IEEE 802.11a (IEEE Std 802.11a-1999) orthogonal frequency division multiplexing (OFDM) channels. Many other arrangements for defining the frequency sub-channels may alternatively be used. By dividing a high throughput multicarrier channel into a number of frequency sub-channels that may be processed separately, problems caused by interference within one or more of the sub-channels may be dealt with by, for
15 example, simply ignoring or not using the affected sub-channels as part of a corresponding wireless link.

Fig. 1 is a block diagram illustrating an example wireless apparatus 10 in accordance with an embodiment of the present invention. The wireless apparatus 10 is capable of supporting wireless communication via a multi-carrier communication
20 channel that is made up of a number of frequency sub-channels. For example, in one possible application, the wireless apparatus 10 may be implemented within a wireless network and be capable of supporting communication within a high throughput channel that includes multiple separate IEEE 802.11a wireless channels having different center frequencies. Other channel arrangements are also possible. Although the inventive
25 techniques have application in all forms of multicarrier systems, the wireless apparatus 10 of Fig. 1 will be discussed in the context of an OFDM-based multi-carrier system.

As shown in Fig. 1, the wireless apparatus 10 may include one or more of: a receiver chain 12, a transmitter chain 14, and an adaptive channelization controller 16. Although illustrated with both a receiver chain 12 and a transmitter chain 14, it should
30 be appreciated that embodiments having only a receiver chain 12 or a transmitter chain

14 may be provided. The adaptive channelization controller 16 is operative for determining which of the individual multicarrier sub-channels supported by the wireless apparatus 10 are to be teamed for use in association with a user at a particular point in time. The adaptive channelization controller 16 may make the determination based on,
5 for example, channel state information 18. The receiver chain 12 receives a multicarrier receive signal 20 from a radio frequency (RF) receiver and processes the signal in accordance with control information from the adaptive channelization controller 16 to generate decoded data 22 at an output thereof. The transmitter chain 14 receives source data 24 at an input thereof and processes the source data 24 in
10 accordance with control information from the adaptive channelization controller 16 to generate a multicarrier transmit signal 26 for delivery to an RF transmitter. In at least one approach, the adaptive channelization controller 16 will continuously update the channelization decision for the apparatus 10 based on the current channel state.

In at least one embodiment of the present invention, as illustrated in Fig. 1, the
15 receiver chain 12 may include: a frequency demultiplexer 30, a guard interval (GI) removal unit 32, a number of fast Fourier transform (FFT) units 34, an adaptive parallel to serial converter 36, an adaptive demapper 38, and a decoder 40. The frequency demultiplexer 30 receives the multicarrier receive signal 20 and separates the signal into multiple portions that correspond to the frequency sub-channels discussed
20 previously. In the embodiment of Fig. 1, for example, the multicarrier receive signal 20 is separated into four output streams by the frequency demultiplexer 30. It should be appreciated that any number of output streams may be generated in this manner in accordance with the invention. As discussed previously, in at least one embodiment, the apparatus 10 is capable of transmitting within a high throughput multi-carrier
25 channel consisting of multiple individual IEEE 802.11a channels (e.g., the four channels having center frequencies of 5180, 5200, 5220, and 5240 MHz, respectively). The frequency demultiplexer 30 may be configured to separate the received multicarrier signal based on these sub-channels. Other arrangements are also possible. Each of the sub-channels will typically include multiple subcarriers that can each be modulated
30 with a corresponding data symbol. In at least one embodiment, analog filtration

techniques are used to perform the frequency demultiplexing, although other techniques may alternatively be used (e.g., digital filtration techniques, a combination of analog and digital filtration techniques, etc.). Any number of individual frequency sub-channels may be defined for a given HT multicarrier channel.

5 The multiple streams output by the frequency demultiplexer 30 may be processed separately from one another. In this manner, potential interference within one of the sub-channels can be isolated from the other sub-channels and thus have little or no effect on the processing of the other sub-channels. That is, it may be decided that the sub-channel having the interference will not be made part of the corresponding
10 communication link, and may thus be ignored. For example, if the adaptive channelization controller 16 determines that the third of four sub-channels is currently being used by another communication link within the vicinity of the apparatus 10, it may decide to use only the other three sub-channels as part of the communication link for a local user. The adaptive channelization controller 16 may then deliver control
15 information to the receiver chain 12 that indicates which sub-channels are presently being used and the receiver chain 12 may thereafter ignore information within the inactive sub-channel during a subsequent receive operation.

 The GI removal unit 32 is operative for removing a guard interval from each of the separated signals output by the frequency demultiplexer 30. Guard intervals are
20 placed in transmitted signals to, among other things, increase the immunity of the signals to, for example, multipath effects in the channel. The individual FFT units 34 (four 64-sample FFTs in the illustrated embodiment) are operative for separately converting each of the separated signals (i.e., each of the sub-channels) from a time domain representation to a frequency domain representation. Although illustrated with
25 a separate FFT for each sub-channel, it should be appreciated that a single FFT (e.g., one 64-sample FFT) may be used with time division access to process each sub-channel separately. The frequency domain representation of each separated signal will include the modulation data points associated with each of the corresponding subcarriers within the signal. Although illustrated as fast Fourier transform (FFT) units, it should be
30 appreciated that any form of discrete Fourier transform may be used.

The adaptive parallel to serial converter 36 receives the data points output by the FFT units 34 and converts the information to a serial stream. The adaptive parallel to serial converter 36 receives control information from the adaptive channelization controller 16 that is indicative of the current channelization scenario for the apparatus

5 10. For example, the adaptive channelization controller 16 may inform the adaptive parallel to serial converter 36 that only some of the supported sub-channels (e.g., a first and third of four sub-channels) are currently teamed for a corresponding user. In one possible approach, the adaptive parallel to serial converter 36 will then generate the serial stream by merging information received in the currently active sub-channels. The

10 received information from the sub-channels that are not presently being used may be ignored. In another approach, the adaptive parallel to serial converter 36 may add zeros (or some other predetermined symbol) to the output data stream in positions corresponding to the unused sub-channels. The adaptive demapper 38 receives the serial stream output by the adaptive parallel to serial converter 36 and demaps the

15 corresponding data based on a predetermined signal constellation. Any of a variety of different modulation schemes may be used including, for example, BPSK, QPSK, 8-PSK, 16QAM, 64QAM, 128QAM, 256QAM, and/or others. In at least one embodiment, the modulation technique may be adaptable based on, for example, current channel conditions, etc. The adaptive demapper 38 may also receive

20 channelization information from the adaptive channelization controller 16 to allow the demapper 38 to adapt to the present channel scenario. The decoder 40 may then decode the demapped data stream to, for example, detect and/or correct errors within the corresponding data.

Referring again to Fig. 1, in at least one embodiment, the transmitter chain 14

25 may include: a forward error code (FEC) coder 42, an adaptive mapper 44, an adaptive serial-to-parallel converter 46, an inverse FFT (IFFT) unit 48, and a guard interval addition unit 50. The FEC coder 42 receives the source data 24 at an input thereof and codes the data based on a predetermined forward error-correcting code. Any of a variety of different codes may be used. The adaptive mapper 44 then maps the coded

30 data based on a predetermined signal constellation to generate signal points at an output

thereof. The adaptive serial-to-parallel converter then converts the stream of signal points output by the adaptive mapper 44 into a parallel format for delivery to the IFFT 48. The FEC coder 42, the adaptive mapper 44, and the adaptive serial-to-parallel converter 46 may each receive channelization-related control information from the adaptive channelization controller 16 that is indicative of the present channelization scheme for a corresponding user. In this manner, zeros (or some other predetermined symbols) may be added to the data in positions corresponding to the sub-channels that are not currently being used in the teamed channel (e.g., using a technique known as puncturing). The IFFT unit 48 (a 256-sample IFFT in the illustrated embodiment) takes the parallel data points output by the adaptive serial-to-parallel converter 46 and converts them from a frequency domain representation to a time domain representation. Because there is no potential interference to be dealt with during the transmit operation, the individual sub-channels are not processed separately by the IFFT 48 as in the receiver chain 12 discussed previously (although in at least one embodiment, the individual sub-channels are processed separately in the transmitter to, for example, simplify the digital processing). The GI addition unit 50 adds a guard interval to the time domain signal output by the IFFT unit 48. The resulting signal is then delivered to the corresponding RF transmitter to be transmitted into the wireless channel.

The channel state information 18 used by the adaptive channelization controller 16 may include any type of information from which the current channel usage scenario may be determined. This may be either a closed loop process, an open loop process, or a combination of the two. In one approach, for example, the adaptive channelization controller 16 may receive the channel state information 18 from the remote side of the communication link. In another approach, the channel state information may be generated locally (e.g., noise-to-signal ratio (NSR) per subcarrier values estimated during a previous packet exchange, etc.). The adaptive channelization controller 16 may use the channel state information to identify, for example, sub-channels that are presently occupied. The adaptive channelization controller 16 may then select the remaining unoccupied sub-channels (or a subset thereof) for use in the corresponding

wireless link. Other factors may also be taken into consideration in making the channelization decision.

In at least one embodiment of the present invention, the inventive principles are implemented within a wireless networking environment. For example, the wireless apparatus 10 of Fig. 1 may be located within, for example, a wireless user device (e.g.,
5 a laptop, desktop, palmtop, or tablet computer having wireless networking capability, a personal digital assistant (PDA) having wireless networking capability, a cellular telephone or other handheld communicator, etc.) and/or within a wireless access point. In a wireless user device, the adaptive channelization controller 16 will often determine
10 (and adapt) a channelization scheme for a single corresponding user. In an access point, on the other hand, channelization schemes may need to be tracked for multiple users simultaneously. Many other scenarios are also possible. The wireless apparatus 10 may also be part of a wireless network interface card or other wireless network interface structure. In at least one embodiment, the wireless apparatus 10 is implemented on a
15 single radio frequency integrated circuit (RFIC). Many other implementations are also possible.

It should be appreciated that the individual blocks illustrated in Fig. 1 may be functional in nature and do not necessarily correspond to discrete hardware elements. For example, in at least one embodiment, two or more of the blocks are implemented in
20 software within a single (or multiple) digital processing device(s). The digital processing device(s) may include, for example, a general purpose microprocessor, a digital signal processor (DSP), a reduced instruction set computer (RISC), a complex instruction set computer (CISC), a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), and/or others, including combinations of
25 the above. Hardware, software, firmware, and/or hybrid implementations may be made.

Figs. 2, 3, and 4 are channel usage diagrams illustrating possible operational scenarios for a high throughput communication device that is capable of operating within four frequency sub-channels in accordance with embodiments of the present invention. With reference to Fig. 2, a high throughput device may monitor its
30 supported channels and notice that an IEEE 802.11a device is currently operational

within a first of the four sub-channels (e.g., frequency sub-channel 1 in Fig. 2). The IEEE 802.11a device may be operative within an entirely different basic service set (BSS) as the high throughput device or within the same BSS. The HT device then makes a decision to operate within the remaining three contiguous sub-channels (e.g.,
5 frequency sub-channels 2, 3, and 4 in Fig. 2). Fig. 3 illustrates a similar scenario, except that the three sub-channels that the HT device decides to operate within are non-contiguous (e.g., frequency sub-channels 1, 3, and 4). Fig. 4 illustrates a scenario in which an HT device determines that multiple sub-channels (i.e., frequency sub-channels 1 and 2 in Fig. 4) are currently occupied by another HT device communicating in the
10 vicinity. The first HT device thereafter decides to operate within the two remaining sub-channels (i.e., frequency sub-channels 3 and 4 in Fig. 4). As will be appreciated, many other operational scenarios may also exist in accordance with the present invention. In a wireless networking environment, the inventive principles may be used, for example, to provide for the coexistence of legacy systems (e.g., IEEE 802.11a
15 systems, etc.) and more modern high throughput systems. The inventive principles may also be used to organize multiple transmitting sessions between several stations by sharing the same frequency band. Another possible use of the inventive techniques in a wireless network is to allow multiple legacy networks using different frequency channels to be merged into a single BSS using a single wireless access point.

20 Fig. 5 is a flowchart illustrating a method 80 for use in implementing adaptive channelization within a multicarrier device that is capable of operating within a high-throughput (HT) channel having multiple sub-channels. First, channel state information is acquired for the HT multicarrier channel (block 82). The channel state information may be developed locally, such as by measurements made by a local receiver, and/or it
25 may be received from a remote entity, such as a communication device at the other side of the corresponding communication link. A decision is then made as to which of the supported sub-channels will be used for a corresponding wireless link based on the channel state information (block 84). In one approach, the channel state information is used to identify which of the supported sub-channels are currently occupied. Sub-
30 channels are then selected from the unoccupied sub-channels. Other selection

techniques may alternatively be used. Sub-channel adaptation information is then delivered to a receiver chain and/or a transmitter chain for use in processing a corresponding multicarrier receive and/or transmit signal (block 86).

5 In the foregoing detailed description, various features of the invention are grouped together in one or more individual embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects may lie in less than all features of each disclosed embodiment.

10 Although the present invention has been described in conjunction with certain embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and the appended claims.